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14 October 1965

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HQ USAF (AFTAC/VELA Seismological Center)
Washington, D. C. 20333

Attention: Major Jack Pantall

Subject: Quarterly Report No. 1, Project VT/5081
1 July through 30 September 1965, Technical Report No. 65-120

Identification: AFTAC Project No: VT/5081
Project Title: Multicomponent Strain Seismograph
ARPA Order No: 624
ARPA Code No: 8100
Contractor: The Geotechnical Corporation, Garland, Texas
Date of Contract: 1 July 1965
Amount of Contract: \$272,651
Contract No: AF 33(657)-15288
Contract Expiration Date: 31 December 1966
Project Manager: R. C. Shopland, BR 8-8102

Gentlemen:

This is a report of work done in the quarterly period 1 July through 30 September 1965 in compliance with the statement of work to be done under Contract AF 33(657)-15288.

1. GENERAL

Work in the first quarter was directed toward five main objectives. They were:

a. To obtain equal phase and amplitude response on the vertical strain and vertical inertial seismograph to measure phase, coherence, and spectra of the seismic noise at WMSO;

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b. To evaluate P-wave enhancement by cancelling microseisms using vertical strain and vertical inertial seismographs, and by utilizing the directional properties of the horizontal strain array;

c. To verify a possible 6 dB loss of signal in the vertical strain seismometer;

d. To start a retrofit of strain instrumentation and strain facilities at WMSO;

e. To set up the data channels required for digital recording by Texas Instruments, Inc.

2. EQUALITY OF PHASE AND AMPLITUDE

Inconsistent phase differences between the vertical strain and inertial instruments were traced to equipment worn out from long use or damaged by lightning. At one time or another in the last 3 months, we have found it necessary to overhaul 2 PTA power supplies; repair three 0.8 cps galvanometers; replace 1 PTA filter; replace choppers in 5 operational amplifiers; and install 2 horizontal strain calibrators damaged by lightning. With consistent phase responses, we were able to establish the existence of a phase discrepancy of the order of 20 degrees in the vertical strain seismograph. The error was traced to the vertical strain calibrator. By comparing the phase response of a horizontal strain seismograph driven first by its own electromagnetic calibrator, and then a magnetostrictive calibrator as used on the vertical strain seismometer, the latter calibrator was found to introduce a phase shift of the order of the discrepancy observed. The final results of the investigation are shown in figure 1. Curve A is the theoretical phase response of both the vertical strain and the inertial seismograph; curve B is the empirical phase response of the inertial seismograph; curve C is the empirical phase response of the strain seismograph corrected for phase error in the calibrator; and curve D is the difference between strain and inertial phase. The average difference is 2 degrees in the frequency range 0.3 to 5 cps. The maximum difference is 7 degrees. The maximum error of the variable-phase function generator used to measure phase is ± 3 degrees.

3. P-WAVE ENHANCEMENT

3.1 CANCELLATION OF MICROSEISMIC BACKGROUND

3.1.1 Vertical strain and inertial data with matched phase responses were recorded on magnetic tape at WMSO. The data were filtered and summed at Garland to cancel 6-sec microseisms. Cancellation was less favorable than the 6 dB cancellation reported in previous work. The poorer cancellation was attributed to the lack of predominant bursts of Rayleigh waves in the sample used.

3.1.2 Similar processing of 0.5-sec microseisms showed the same lack of consistency of phase between vertical strain and inertial data as was found in previous work. Both 6-sec noise and 0.5-sec noise will be digitized and adjusted to equal amplitude response to improve cancellation. However, only a small improvement is expected.

3.1.3 Samples of background noise can now be collected to measure spectra, coherence, and phase between vertical earth displacement and differential displacement.

3.2 DIRECTIONAL DISCRIMINATION OF NOISE

Enhancement of P waves on the strain array is not yet evaluated. Collection of data will begin in mid-October.

4. LOSS OF VERTICAL STRAIN SIGNAL

To resolve the question of whether signal is being lost in the vertical strain seismometer, a magnetostrictive (MS) calibrator of the same design as the one used in the vertical strain seismometer has been mounted on the north horizontal strain seismometer. This arrangement allows the use of a variable-capacitance transducer to measure the motor constant of the MS calibrator. The test data being taken at the time of this writing should help resolve the question of loss of signal.

5. INSTRUMENTATION

5.1 SEISMOGRAPHS

5.1.1 During the reporting period, the six seismographs shown in the block diagram of figure 2 were installed, and they are now being calibrated. Operating parameters are listed in Table 1. Essentially, they consist of three orthogonal short-period Johnson-Matheson seismometers operating into 10-cps galvanometers, and three orthogonal moving-coil strain seismometers operating into 0.8-cps galvanometers. Equal phase response to Rayleigh waves is achieved in channels 1, 2, 3, 4, 5, 8 and 10 by matching the 10-cps galvanometers in the inertial system with 10-cps high-cutoff filters in the strain system, and by inserting single-stage integrating filters in the horizontal inertial channels. Analog data from in-phase channels will be recorded on magnetic tape to measure phase, coherency, and spectra of both microseisms and signals among various seismographs, including the summed horizontal strain output. Microseisms will be studied to determine the feasibility of cancelling microseisms in all portions of the frequency band from 0.1 to 10 cps. Phase relations will be studied to evaluate the usefulness of the strain and pendulum combinations in the discrimination between wave types and between earthquake phases.

5.1.2 To achieve equal amplitude responses to Rayleigh waves for the six components, channel 5 is replaced by channel 6. In effect, the signal from channel 5 is integrated to become the signal of channel 6.

5.1.3 It is important to note that a new combination of horizontal strain and inertial instruments has been designed, lab tested, and installed in the directional array. Original plans included the use of variable-capacitance (VC) transducers on the strain seismometer and the use of long-period horizontal inertial seismometers. The new combination utilizes moving-coil transducers on both the strain and the inertial seismometers, as explained in paragraph 5.1.1. The change also allows operation of a three-component orthogonal strain system with matched phase and amplitude responses.

5.1.4 To provide Rayleigh waves in phase and with equal amplitudes for studying the P-wave coda, data from the vertical strain (channel 1) can be shifted 90° relative to data from the vertical pendulum (channel 6), by either analog or digital techniques without changing the amplitude response.

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5.1.5 In-phase data from channels 1, 2, 4, 5, 8 and 10 will be available for digital recording by Texas Instruments, Inc. starting 15 November 1965 as planned.

5.2 IMPROVED PTA SHELTER

A 10 x 14 ft Parkersburg prefabricated steel building is being transferred from UBSO to WMSO for use as a shelter for phototube amplifiers. Design of the foundation for the building is complete and approval for erection of the building has been requested from the Commanding General, Ft. Sill, Okla. Preliminary contact has been made with contractors to obtain bids for pouring a monolithic slab foundation for the building. The building will be erected by the Fox Construction Company of Oklahoma City, the franchised Parkersburg dealer in Oklahoma.

5.3 SYSTEM IMPROVEMENTS

All lines to and from the vault and the borehole will be run in conduit to eliminate the lightning problems which have been encountered heretofore. New lines will be run from the Remote Operating Facility (PTA shelter) to the Central Recording Station. AEI lightning protectors will be installed on these lines. The new lines are being installed to reduce crosstalk and ground-loop problems which are due to line leakage. All material for the above improvements is either in house or on order.

5.4 STRAIN HOUSING IMPROVEMENTS

A ship's door for the horizontal strain central vault has been ordered. Delivery of the door is scheduled for the week of 4 October 1965. Upon completion of the PTA shelter and the system improvements, the entrance to the strain vault will be extended and an additional 4 feet of overburden will be placed over the entire strain array to reduce noise due to temperature variations and wind.

6. ACTION REQUIRED BY THE GOVERNMENT

No action is required at this time.

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7. FINANCIAL STATUS

7.1 EXPENDITURES TO DATE

Total estimated expenditures through 30 September 1965 are \$24,700.

7.2 MAN-MONTHS EXPENDED TO DATE

Fifteen man-months of technical effort have been expended to date.

7.3 OVERRUN POSSIBILITIES

The funds available under Project VT/5081 appear adequate and no overrun is anticipated.

Very truly yours,

TELEDYNE INDUSTRIES, INC.
Geotech Division

Robert C. Shopland

Robert C. Shopland
Senior Physicist

RCS/et

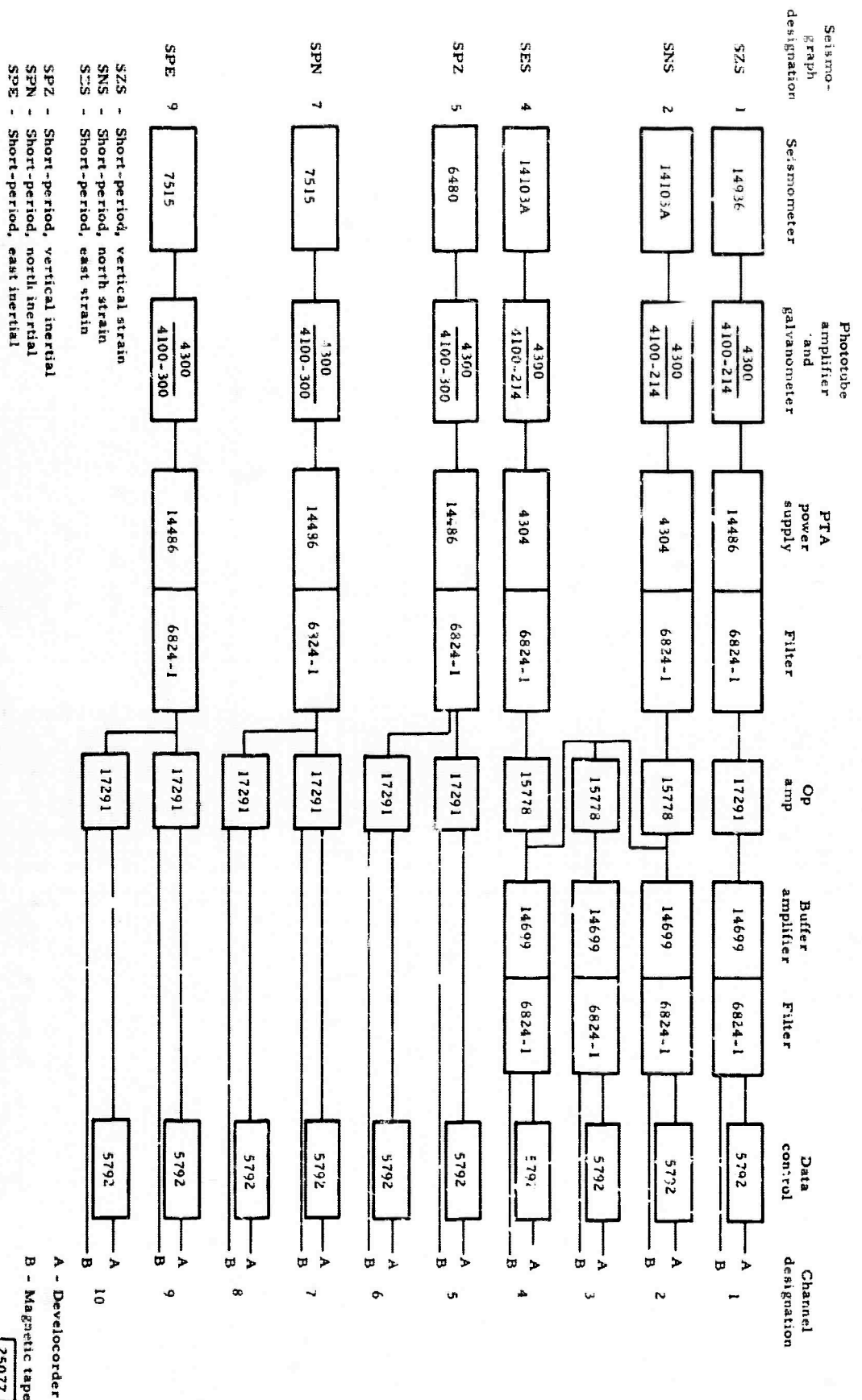


Figure 2. Block diagram of short-period strain and inertial seismographs being set up at WMSO

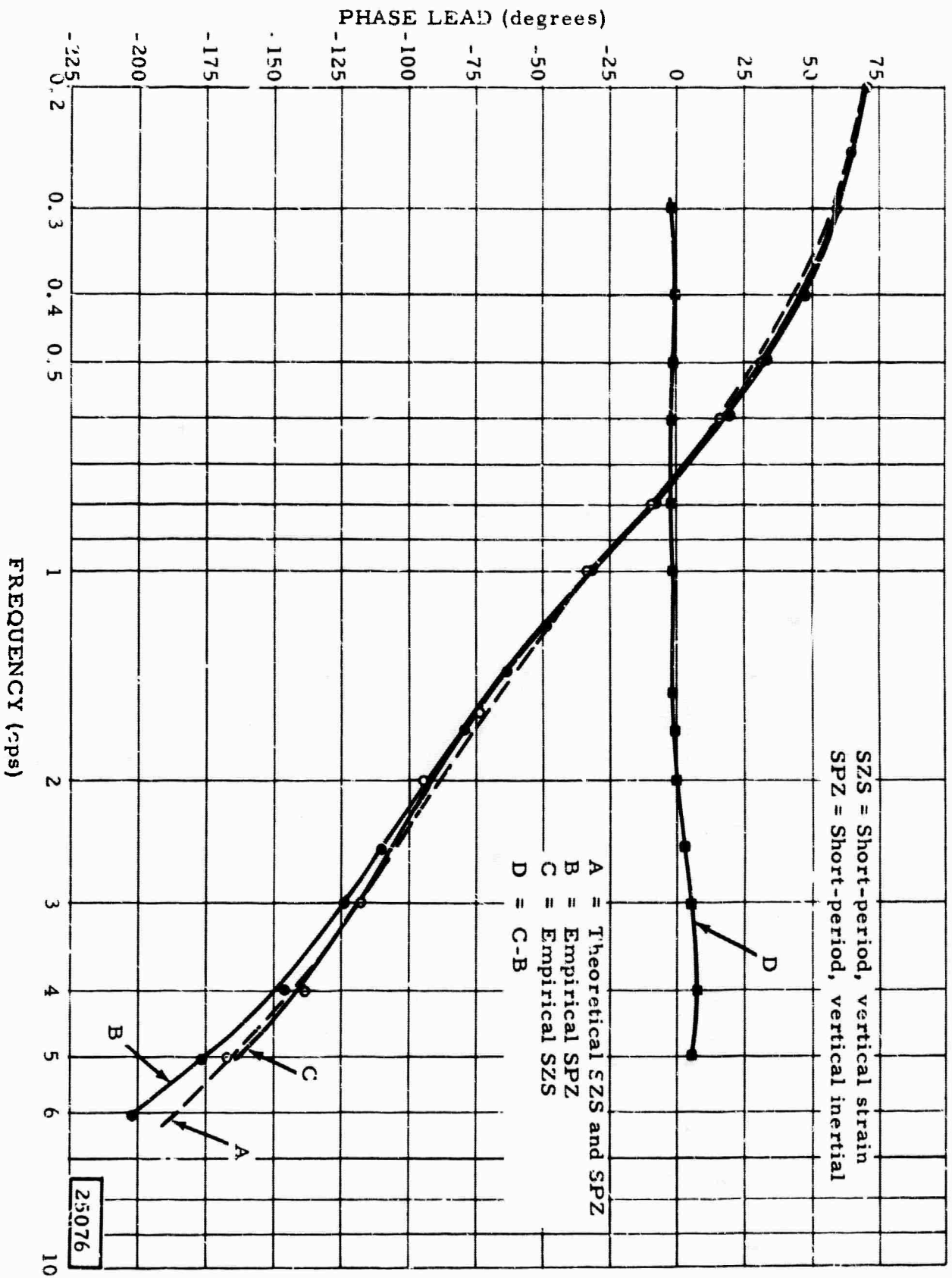


Figure 1. Phase response curves showing close match between vertical strain and vertical inertial seismographs

Table 1. Instrument operating parameters

	<u>Seis</u>		<u>Galvo</u>		<u>PTA filter</u>		<u>Buffer filter</u>	
	<u>f_n</u> <u>(cps)</u>	<u>λ</u>	<u>f_n</u> <u>(cps)</u>	<u>λ</u>	<u>Low</u> <u>cutoff</u> <u>(cps)</u>	<u>High</u> <u>cutoff</u> <u>(cps)</u>	<u>Low</u> <u>cutoff</u> <u>(cps)</u>	<u>High</u> <u>cutoff</u> <u>(cps)</u>
SZ	80	0.06	0.8	0.7	0.01	10	0.01	10
SN	65	0.06	0.8	0.7	0.01	10	0.01	10
SE	65	0.06	0.8	0.7	0.01	10	0.01	10
SPZ	0.8	0.7	10	0.7	0.01	10	-	-
SPN	0.8	0.7	10	0.7	0.01	10	-	-
SPE	0.8	0.7	10	0.7	0.01	10	-	-